

# *Digital Transformation*

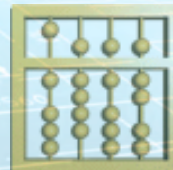
## A Game Changer

### *How Does the Digital Transformation Affect Informatics as a Scientific Discipline?*

Manfred Broy

TECHNISCHE UNIVERSITÄT  
MÜNCHEN  
INSTITUT FOR INFORMATICS

**TUM**



**ZD.B**

ZENTRUM  
DIGITALISIERUNG  
BAYERN

## Digital transformation is ...

... the change of the analog to digital, leading to virtual forms of information processing by

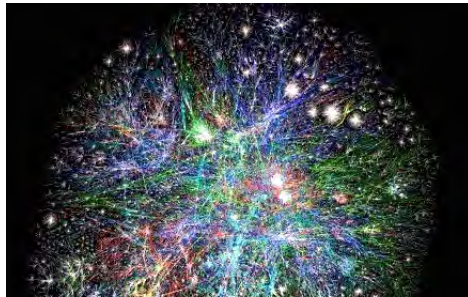
- ◇ application of digital technology,
- ◇ roll-out of digital infrastructure,
- ◇ development and usage of digital applications
- ◇ digital business models

and the induced changes in

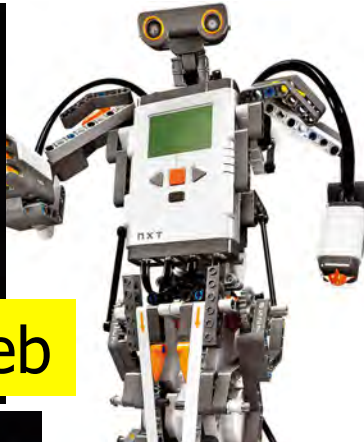
- ◇ economy and industry
- ◇ society
- ◇ politics
- ◇ science
- ◇ education
- ◇ private life



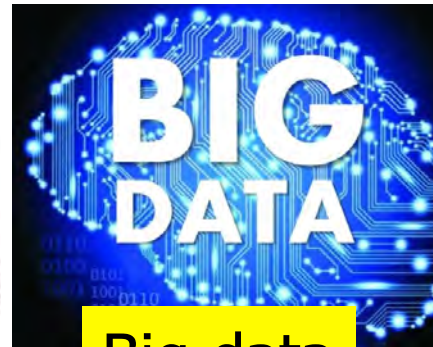
# Digital technology – changing the world



World Wide Web



Robotics



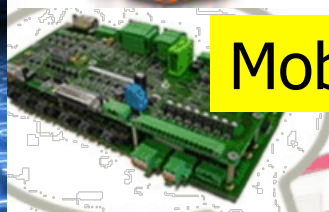
Big data



Smart phones



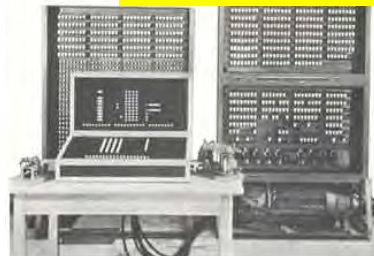
Internet



Mobile communication



Graphical user interfaces



ECCS 2016 in Budapest



Data processing



Embedded systems



High performance computing

# The elements of digital change

- Digital Technology – *Technology Push*
  - ◇ Information and communication technology
  - ◇ Data and software
- Digital Infrastructure
  - ◇ devices, embedded systems, networks, ...
- Digital Application – *Market Pull*
  - ◇ Diverse application areas (business, traffic, Medicine, Energy, Communication, entertainment, ...)
- Digital business models – *Business Opportunities*
  - ◇ Digital value chains
- change in den enterprises – *Start Ups*
  - ◇ enterprise networks
- Change of individuals' behavior and understanding of the world



dynamics result of  
an intensive mutual  
reinforcement

# Who will be transformed?

- Individuals
  - ◇ new ways to manage everyday life
  - ◇ digital literacy
- Economy – digital transformation
  - ◇ enterprises
  - ◇ start ups
- Education
- Science
- Technology
- Environment
- Society
- State, politics, and governance
- **literally everything!**



# Drivers of digital change in the economy

- Innovative functionality
  - ◇ high acceptance, rapid adoption
- Cost pressure by rationalization of services
  - ◇ New financial models (advertising, data acquisition, ...)
- New competitors by networking
- Monopoles – acceleration effects by scaling
- Modular value chains
- Automation by innovative software
- Getting rid of locality in the market
- New business models by synergy, networking and composition
- Scaling effects – the winner takes it all
- Breath taking speed
- ...



**Drivers:  
Technology and Infrastructure**

## Drivers ...

---

- **Moore's Law:**  
the computing power of digital hardware grows exponentially  
(doubling the performance all 1 1/2 years with equal cost)  
    In 10 years: Factor 100  
    In 20 years: Factor 10.000
- **Digital networks** – transmission power grows exponentially
- the flexibility of **programmable** hardware:  
the same Hardware can by programming (by **Software**) be used for  
completely different tasks  
– **example Skype**
- the literally **unlimited range of the fields of applications**  
In practically every area of application hardware/software systems  
open up new possibilities  
Information Systems as part the reality – augmented reality



# Key Areas of Technology and Application

---

## Technology

- Data Processing
- Embedded Systems
- Personalized Computation
- High Performance Computing
- Search Engines
- Mobile Communication
- Data analytics
- Autonomous systems
- ...

## Areas of application

- Process and Data Management
- Social Networks
- Internet search
- Smart phones
- Advanced Assistance
- Connected car
- Digital health
- ...

dynamics is result of an intensive mutual reinforcement

---

---

**Change the instruments  
and you will change the  
entire social theory that  
goes with them!**

Latour, B. (2009): Tarde's idea of quantification, in: The Social after Gabriel Tarde: Debates and Assessments, Routledge, London, pp. 145– 162

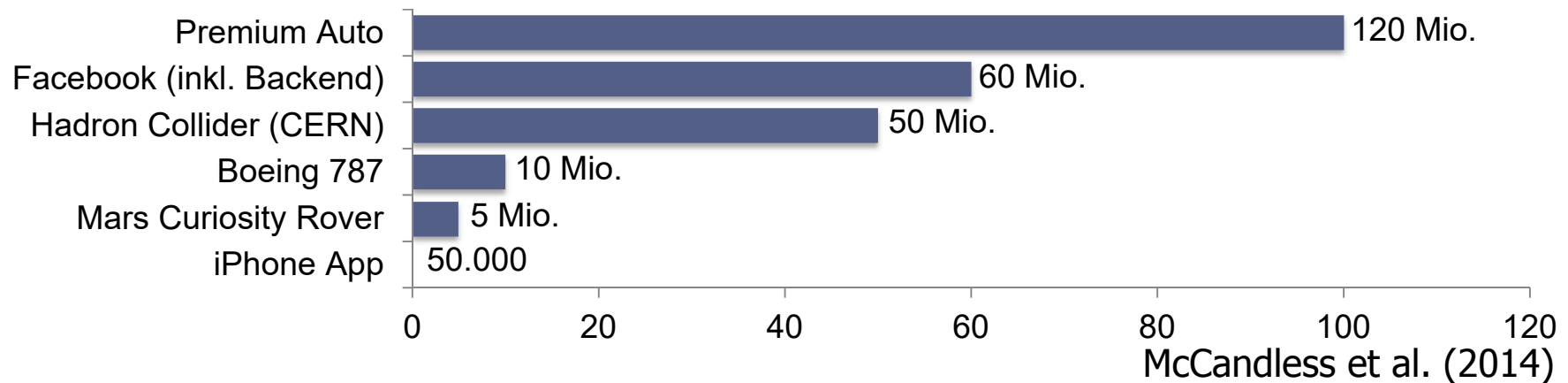
# Long-term implications of technological progress

"software is eating the world" (Marc Andreessen, venture capitalist, 2011)

- software will revolutionize the technology and computer industries
  - ◇ value of technology does not lie in hardware but software
- software will transform many industries
  - ◇ for example, by digitizing waning importance of traditional print media
- software will fundamentally change all industries
  - ◇ any kind of value is can be mapped by software

Deeply affected areas: mobility, media, manufacturing sector, financial sector, healthcare, education, legal system, ...

## Industry example: Lines of Code



# Current Technology trends

- Big Data
- Cloud Platforms
- Virtualization
- Autonomy System
- Context Awareness
- Human Centric Systems
- Digital Engineering
- Augmented Reality
- ...



# **Drivers: Applications**

# Das World Wide Web permits den worldwide access auf

- a universe of data, images, services, sounds, videos, ...



# World Wide Web

---

- **World Wide Web:** network of information with
  - ◇ HTTP as protocol, for the browser getting information by calls of the Webserver
  - ◇ HTML as document description language, for defining, how the information is structured and how the documents are related (Hyperlinks)
  - ◇ URLs as unique address (z. B. a Web page), used in Hyperlinks.
- **Web 2.0:** interactive and collaborative elements of www - social media
- **Web 3.0:** Semantic Web
- **Future Internet** - Mobile IP
- **Internet the Dinge and Services** - CPS

# The Internet of Things: What's that?

---



# IoT: Internet of Things: Real world aware Internet: What is it?

- Simple idea: things get Internet addresses and connected to the Internet.
- More directly
  - ◇ devices (Traffic lights, cell phones, cars, airplanes, buildings, ...) will become embedded software systems directly affiliated to the Internet
  - ◇ Exchange of mutual information and use of mutual services
  - ◇ Direct Internet access from and to the physical world
- The Internet and the World Wide Web gets real **world aware**

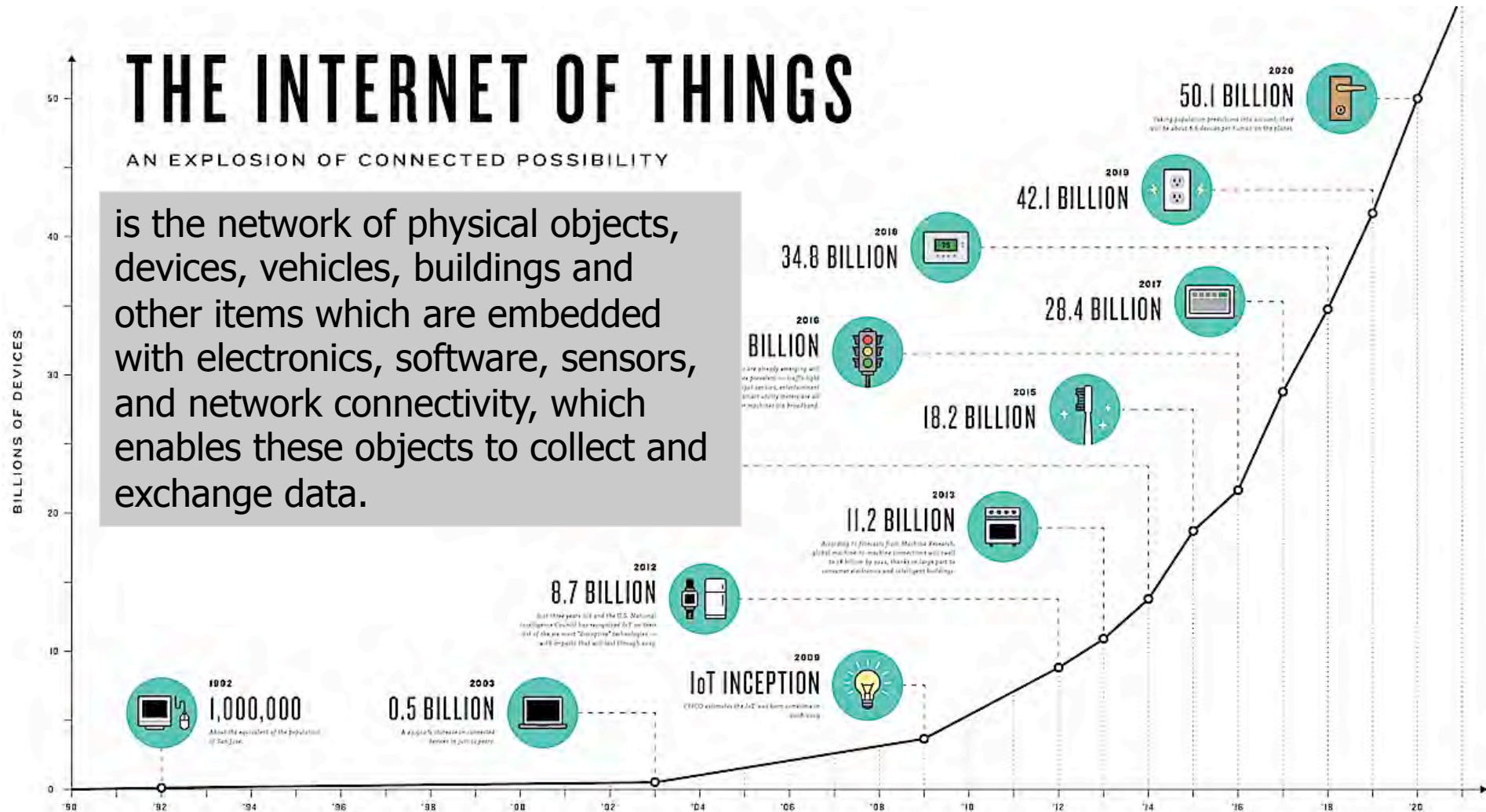


# ... to the Internet of things

## THE INTERNET OF THINGS

AN EXPLOSION OF CONNECTED POSSIBILITY

is the network of physical objects, devices, vehicles, buildings and other items which are embedded with electronics, software, sensors, and network connectivity, which enables these objects to collect and exchange data.



# From the Internet of things to cyber-physical systems

- Real world awareness
  - ◇ Ubiquitous systems
  - ◇ Pervasive systems
  - ◇ Services with direct physical impact
  - ◇ ...
- Advanced assistance
- Adaptivity
- Autonomy
- Real time access from devices
- Sensors and actuators everywhere
- The human in the loop
- ... it is the Internet of data and things connected to systems interacting with humans



# The Ongoing Digital Transformation ...

---

- fusion of **information and communication technologies** with **engineering of physical systems**
  - ◇ has triggered tremendous changes in private and public sectors.
- These changes deeply influence
  - ◇ the nature of systems we build,
  - ◇ the technologies we use for development and manufacturing and
  - ◇ the way we teach engineering.
- resulting in new generations of **Cyber-Physical Systems (CPS)** and their emerging platforms such as the **Internet of Things (IoT)** and **Industrial Internet (II)/industry 4.0 (I4.0)**
  - ◇ require bringing together competences both from the information technologies and the engineering disciplines.
- As a result, academia, industry, and society will need to
  - ◇ expand capacity in the area of creating CPS in a **dependable** way.

# Cyber Physical Systems: System interact with the Internet



## ... the Internet of cyber-physical systems (IoCPS)

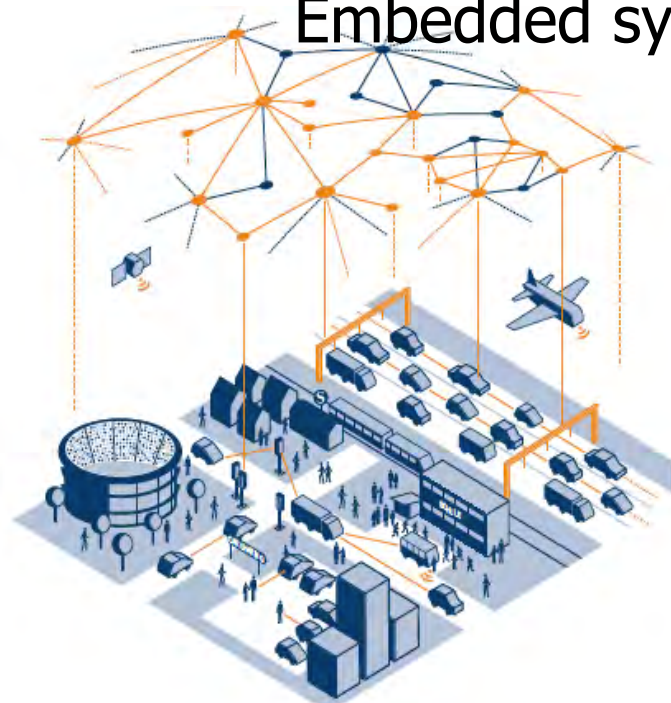


The two sides of CPS



The Internet becomes **real world aware**

Embedded systems get **connected to cloud services**



## Key technology information and cyber security

Security is the most severe challenge and the largest difficulty for usage of digital technology:

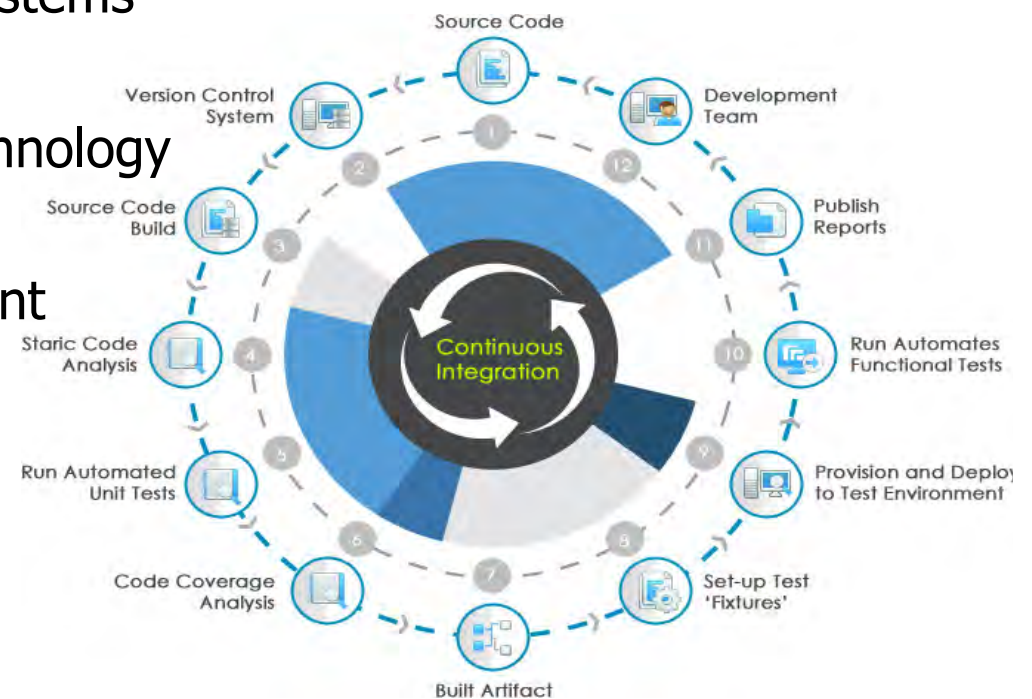
- protecting data
- protecting against digital attack
- protecting critical infrastructure
- protecting privacy

...

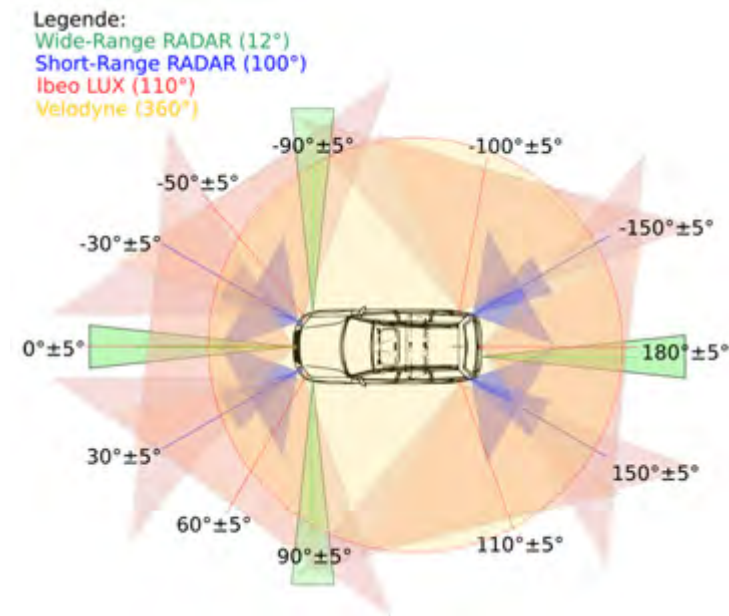
# **Areas of Application**

# Key application areas of CPSs

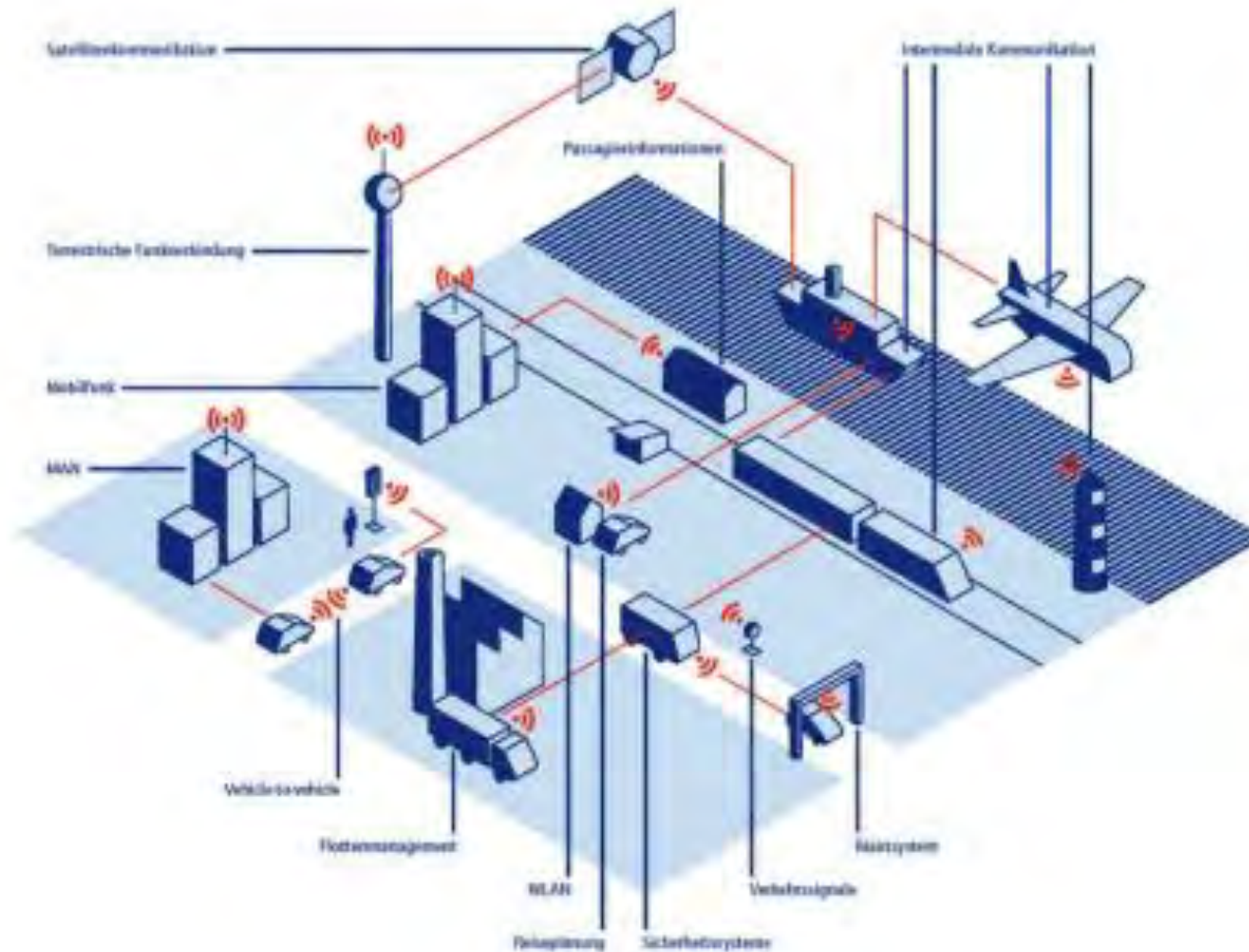
- traffic
    - ◇ transportation systems: train, car, ship, air plane
    - ◇ traffic control
    - ◇ connected traffic
  - logistics
  - medical devices and support systems
  - communication
  - automation and production technology
  - facility management
  - consumer systems / infotainment
  - banking / financial sector
  - energy
  - defence
  - ...
- and their mutual integration



# Street traffic of the future ...

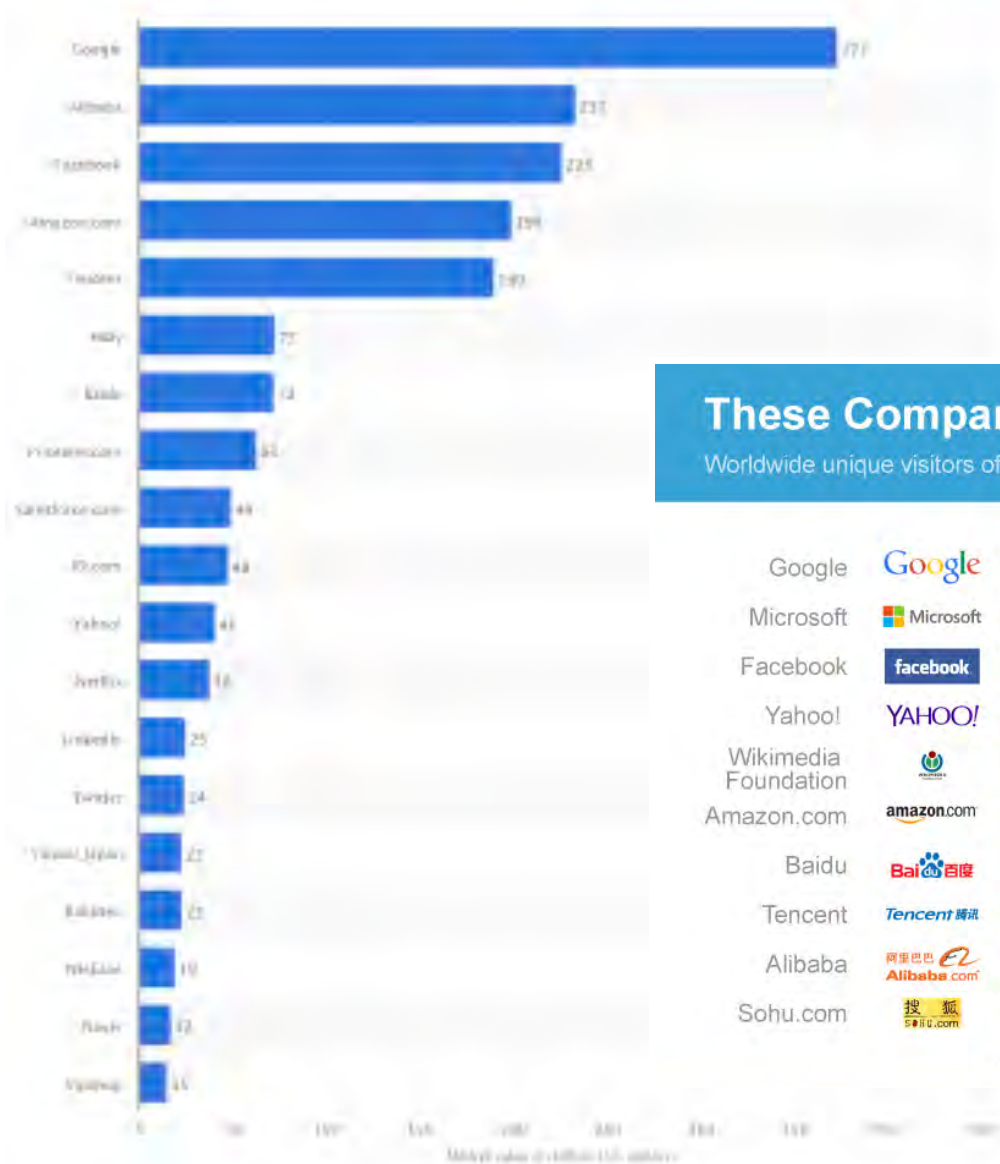


# Vernetzte Industrie – Industrie 4.0



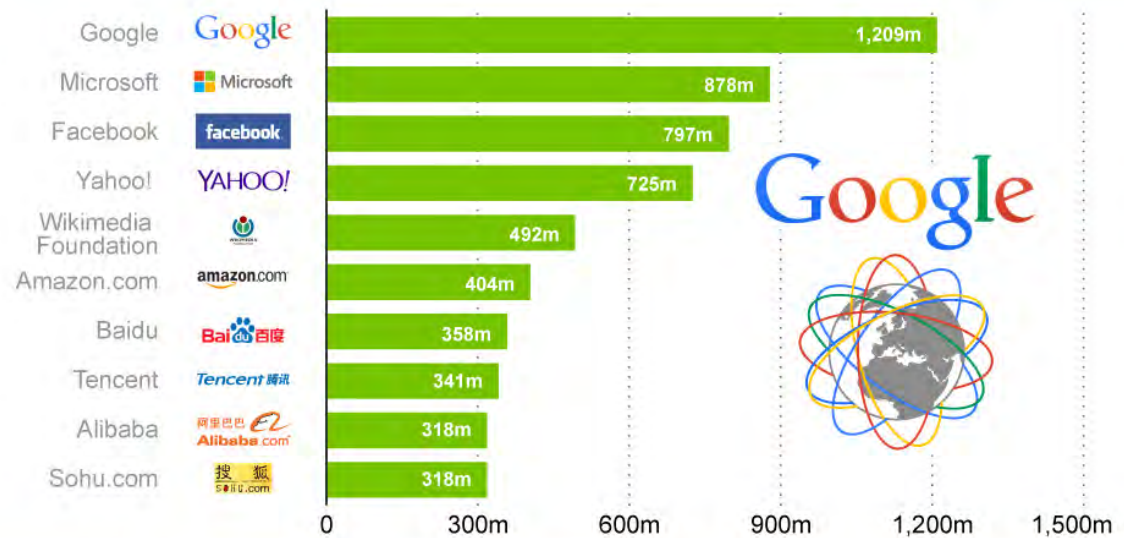
# **Digital Transformation of Economy**

# Dominance: Internet enterprises



## These Companies Control the Internet

Worldwide unique visitors of web properties owned by the following companies in July 2013 (in millions)



# Challenges

## Key innovation drivers

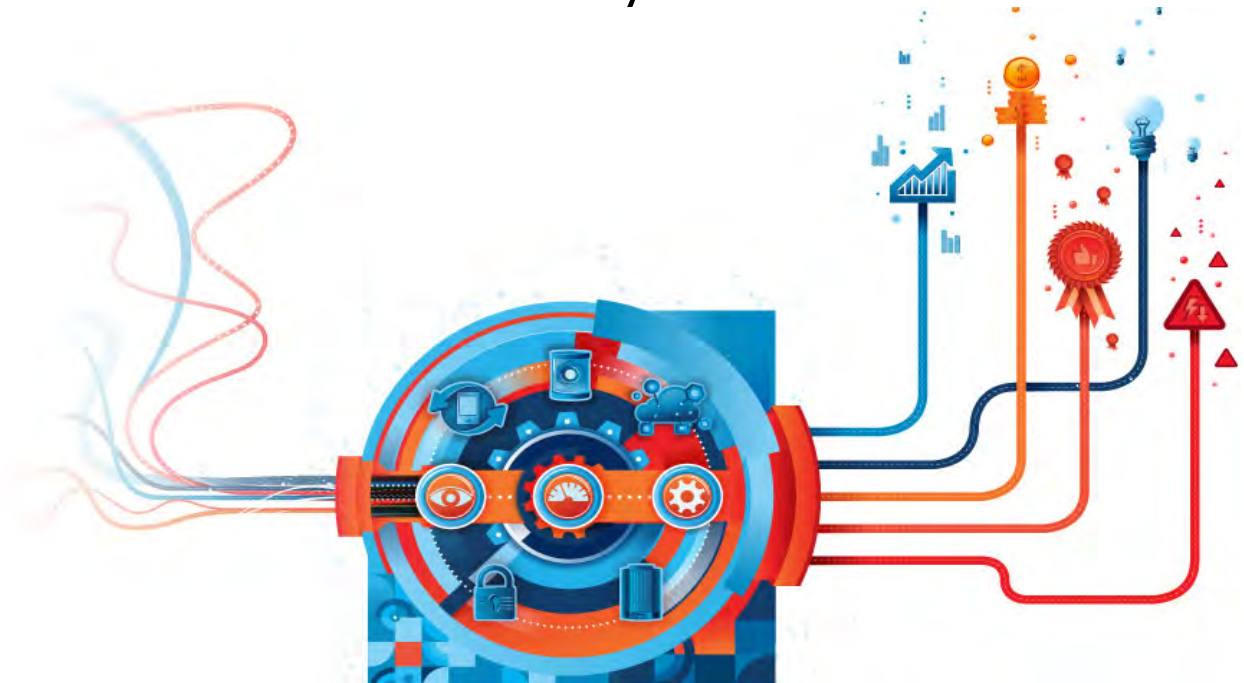
---

- The real world integrates part of the cyberspace
  - ◇ Embedded systems as part of the physical use data and services from the internet
  - ◇ Embedded systems are closely integrated with cyberspace (remote diagnosis, remote update, ...)
  - ◇ Systems of systems with the internet as integration platform
  - ◇ Augmented reality
  - ◇ Fusion of digital and physical world
- Human factors – the human in the loop
  - ◇ Advanced assistance
  - ◇ Human centered engineering
  - ◇ The personal data in the cloud
  - ◇ Cyborgs – augmented human identity



# Engineering challenges

- Platforms
- Architectural concepts
  - ◇ Service oriented architectures
  - ◇ Mastering interoperation and integration
- Requirements eng
- Evolution
- Interoperability
- Context aware
- Human centric
- Autonomy
- Data analytics
- Dependability
  - ◇ Security
  - ◇ Safety
  - ◇ Reliability



# Human factors

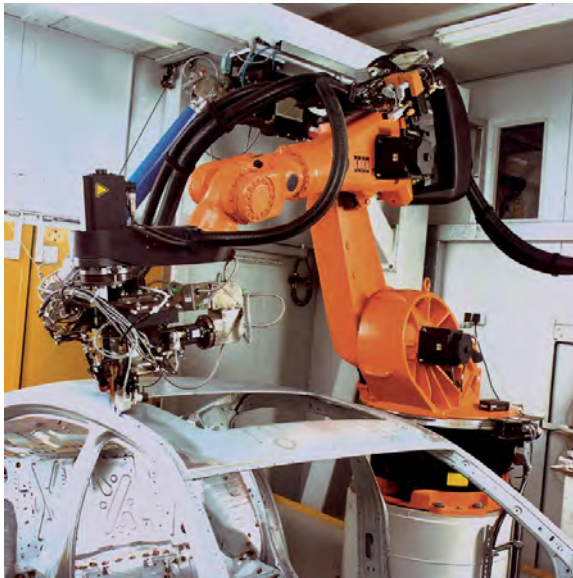
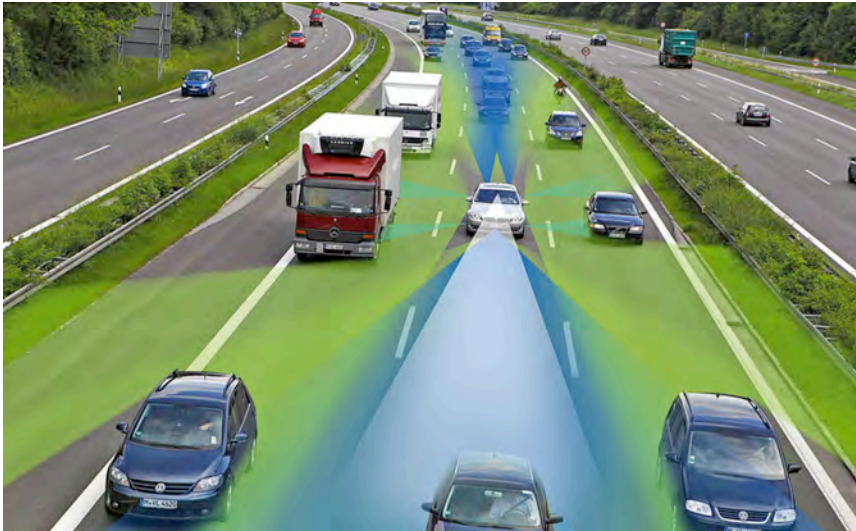
---

- Humans in the loop – **human-centric** cyber-physical systems (HC<sup>2</sup>PS)
  - ◇ Requirements for **human-centric** systems
  - ◇ design of HMI
  - ◇ Deep assistance

CPS have deep impact on human behavior

- Acceptance
  - ◇ Which services to humans accept
  - ◇ What about privacy
- Human social mediator networks
  - ◇ Monitor health and emotional states
  - ◇ Mediator of human/human interaction
- Integrated socio-cyber-physical systems
  - ◇ Example. air traffic control

# Software is everywhere



# Software everywhere – data from everywhere ...

## Ubiquitous Intelligent Services



Google glasses



Smart Labels

## the future ...

---

### Total connectivity?

- Computer embedded everywhere?
- Information totally connected - just in time?
- Automatized Reaction – just to the point?
- Integrated Assistance?
- Multimodale Communication?
- Data Mining?
- Social Networks?
- Autonomy vehicles?
- Business Intelligence?
- ...



# Key Issues

## Key Issues for politics

---

- Can the State influence digital technologies decisively?
- Why Start Ups?
- Why is the Internet so dominant?
- Is it only economy?
- Where is education in the digital change?
  - ◇ Digital Media as cultural technology



# Software as key technology: Software is Eating the World

- Software is auf all levels more and more key technology
  - ◇ functionality
  - ◇ Platform
  - ◇ Application - Apps
  - ◇ Nets
  - ◇ development
  - ◇ dependability  
safety, security, reliability
  - ◇ ...
- the mastering the software technology is to central innovation and competition success factor
  - ◇ exploitation and penetration the application domains
  - ◇ designing processes with connectivity between functions
  - ◇ individualization of systems



## Digital – closer to the human

---

- Digital technology, media, data and services lie closer to the human than any other technologies.
  - ◇ tightly coupled with central human thinking- and patterns of behavior (Communication, social relations, personal data, preferences, notions, ...)
  - ◇ high attractiveness
- Internet-enterprises have a more direct contact to customers how no one else!
- Human centric engineering is **the** success factor!
- Goal: shaping digital technology to create humane systems



## The specific relevance of informatics for human society

- Informatics tools
  - ◇ lead auf new forms the communication and social interaction
  - ◇ improve our physical as well as our cognitive possibilities
  - ◇ enable and suggest new views onto the world
  - ◇ create new possibilities and need therefore legal and ethics rules
  - ◇ complement our world by a digital shadow world (not Second Life but digital mirror in the „Cloud“)
  - ◇ change the power structure (social, economical, legal, political, military ...)

... and need a intensive discussion for controlling the their design!

# SWOT analysis – informatics in Europe

---

## Strengths

- High technical and economical impact
- Well established scientific discipline
- Fast progress

## Weaknesses

- Missing expertise in political and economical leadership
- Weaknesses in Europe in key areas (internet ...)
- Informatics as a scientific discipline too unaware of the changes
- Role of informatics not visible enough

## Opportunities

- High interest in the field
- Innovation driver
- Importance opens new options
- Affects all scientific fields
- Interest by students increasing
- New research challenges

## Threads

- Field dominated by short term economical interests
- Other discipline form their own approaches
- Strong companies take over the field

## ... consequences for Informatics

---

- from software to systems engineering
- from conventional sequential algorithms to interactive processes
- from abstract, discrete, digital modeling (by two valued logics logic) to
  - ◇ modeling interactive behavior
  - ◇ probabilistic models
  - ◇ discrete und continuous time
  - ◇ continuous input/output (control theory)
- informatics as part of our reality
  - ◇ effects of informatics systems in complex environments
  - ◇ modeling of the operational contexts

## ... Consequences for Informaticians

The task of informaticians changes

- from the design of programs on stand-alone computers and
- the solution medium size problems by programming

to

- the development of huge software systems
- connected

- ◊ to the physical reality
- ◊ to data and services in networks

- in close interaction to users

to

- designers of digital future worlds

to

- strategic leadership in enterprises.





# What has changed ...

---

## InformatICS

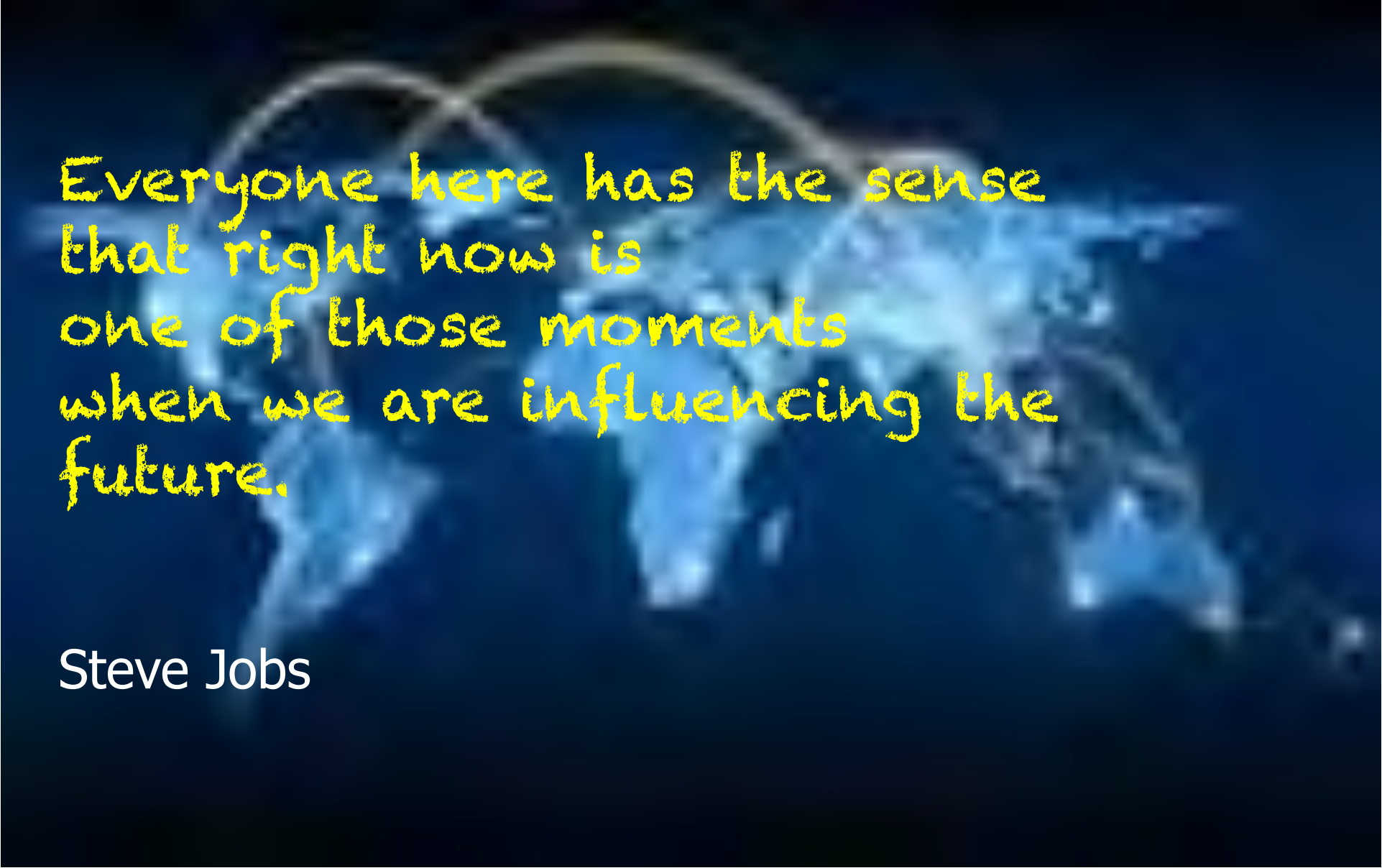
- is a scientific discipline with perhaps the **highest economic impact** currently
  - ◇ **disruptive changes** for the old economies
  - ◇ economic impact of subfields so high that companies take over the field (machine learning, robotics, ...)
- is about to **change** not only economy but also **politics** perhaps **democracy** and **sociological structures**
- is **changing** the way people organize their **everyday life** and their **social relationships**
- can **revolutionize** our **education system**
- may significantly **influence** the political and military **power** in a rapidly changing world, the role of third world countries
- may develop systems that **overrule people** and determine the work and leisure situation
- brings in new threads related to **cyber security**

**How do we respond?**

## Our responsibilities as academic informaticians

---

- Shape the interaction in interdisciplinary work
- Update our curricula to the new topics
- Provide some counterpart to the booming economy
- Educate our students to prepare them for
  - ◇ economic leadership
  - ◇ understanding the digital revolution and their impact
- Give advice to politics and enterprise management
- Contribute to the public discussion
- Develop an ethical position
  - ◇ privacy
  - ◇ autonomous systems
  - ◇ right to informational self-determination
- Further develop the philosophy of science for informatics



Everyone here has the sense  
that right now is  
one of those moments  
when we are influencing the  
future.

Steve Jobs